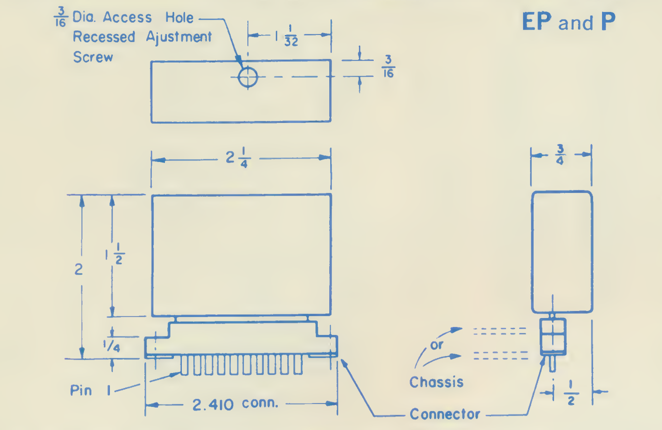
BULLETIN 6111
December 1966

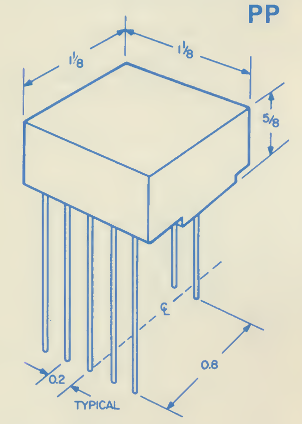
Philbrick Solid State Operational Amplifiers

PHILBRICK produces a wide variety of cool, reliable, solid state operational amplifiers to meet the gamut of application requirements in measurement, computing, control, data processing, and testing. The units shown in this chart are the most popular types now in production. In addition to these, Philbrick is developing new and improved types to meet the ever-increasing challenges to operational amplifier performance. Besides basic amplifiers, one can obtain voltage and current boosters, regulated dc power supplies, non-linear transconductors and operational manifolds from Philbrick. You are invited to discuss the application of operational amplifiers to the solution of your problems with Philbrick or our nearest Representative.

EP and P



PP



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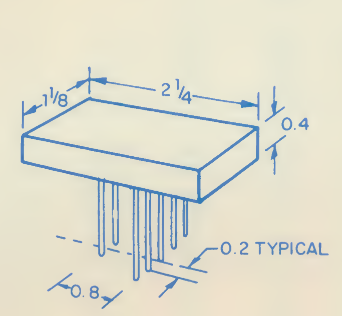
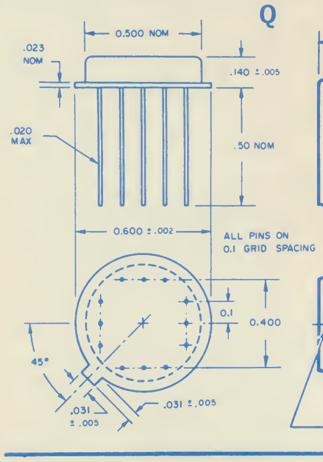
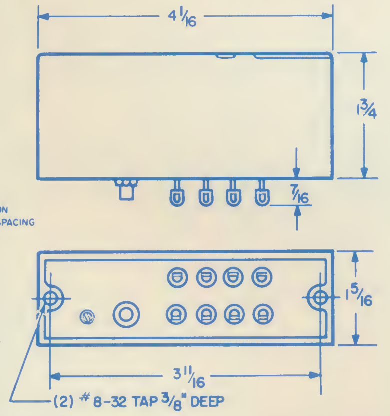


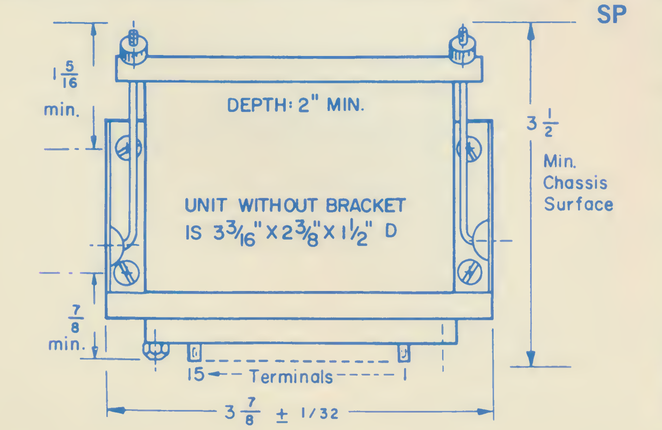
Q



P2A



SP



UTILITY-GRADE

Philbrick Utility-Grade Amplifiers, identified by the letter "U" following the family number (e.g.PP85AU), are identical to premium-grade prototypes in circuitry, layout, manufacturing techniques, and the exclusive use of silicon transistors and first-grade passive components from leading U. S. manufacturers.

The substantial price difference between premium and utility-grade amplifiers is achieved by the following means:

> The use of silicon transistors encapsulated in highly moisture-resistant silicone plastic (Note: not epoxy!) instead of hermetically-sealed amplifiers.
>
> Use of capacitors which are guaranteed from −55 to +85°C, instead of the −65 to +125°C units normally used in Premium-Grade products.
>
> All room-temperature tests are carried out with the thoroughness that has earned Philbrick an enviable reputation for reliability; **complete** temperature tests are run on representative samples of each production run to confirm compliance with published specifications.
>
> Use of date codes and go-no-go tests instead of serial numbers and recording of data as normally required for all premium units (Government Inspection and/or certified test results are available, upon request, for **premium** units.)

In performance, the Utility-Grade amplifiers (except those in the P2 Series) are identical to their Premium-Grade counterparts. As temperature tests are conducted on samples only, tolerances outside the 10°–60°C range are relaxed as compared with the corresponding specifications for the premium amplifier.

Philbrick Utility-Grade amplifiers may be substituted in virtually all applications for which their Premium-Grade counterparts are and have been originally recommended.

CURRENT COMPENSATION

Philbrick differential operational amplifier families P35 through P85 contain input stages with matched pairs of junction transistors in a common emitter configuration. Emitter current being kept constant, each transistor requires a "housekeeping" current into its base amounting to emitter current divided by β (current gain). By selecting high-β transistors and low emitter currents, these base currents can be made as small as 10^{-8} amperes, but they can never be eliminated, and they increase as temperature decreases. If the base currents of input transistors are not supplied by current sources within the amplifier, an output voltage error will result because this offset current produces a voltage drop across the feed-back impedance (in an inverter) or the signal source impedance (in a voltage follower).

The simplest form of base current supply is a resistor from +B to each base. P45A, P55A, P65A and P85A families have these built in, while the proper resistance values for external installation are marked on their PP equivalents. Although these current trim resistors are inexpensive, they are most effective within narrow temperature limits and where high common-mode voltages do not occur. After all, β, and with it base current do change with temperature, and a resistor is a constant current source only as long as the voltage across it remains constant!

Philbrick Current Compensated Amplifiers, identified by the letter C following the family number, have built-in base current sources which closely track current demand over the entire operating temperature range.

The P35C and P85C series contain a sophisticated compensating circuit which leaves the outstanding common mode voltage rejection ratio, the common mode voltage range, and the input impedances unaffected. An additional feature of this compensating circuit is a provision for nulling either input current completely by applying an adjustable voltage bias (±5 volts maximum) to a terminal provided for the purpose. The P45C and P65C series contain a simpler compensating circuit which provides a fivefold decrease in offset current over the entire temperature range, but also reduces the common mode rejection ratio, the common mode voltage range, and the input impedance.

CHARACTERISTICS Typical at +25°C unless otherwise indicated	**PP12Q** Battery operated High input impedance Low offset current	**PP18Q** Battery operated Differential	**PP25A** High input impedance Low offset current	**Q25AH** Differential Wideband Low offset current	**PP35A** Differential High input impedance Low voltage offset	**PP35C** Differential Input current compensated High input impedance Low offset voltage	**PP45** Ultra wideband Large output current
1. **VOLTAGE GAIN (DC open loop)** At +25°C, rated load, ...min. 10 kΩ load, ...min. 100 kΩ load, ...min. At −25°C, rated load, ...min. At +85°C, rated load, ...min.	 5,000 20,000 30,000 2,000 2,000	 5,000 20,000 30,000 2,000 2,000	 40,000 80,000 150,000 30,000 60,000	 20,000 35,000 80,000 15,000 15,000	 100,000 200,000 1,000,000 40,000 150,000	 100,000 200,000 1,000,000 40,000 150,000	 50,000 200,000 300,000 20,000 100,000
2. **RESPONSE (open loop, inverting)** Small signal: Unity gain-bandwidth ......min. Gain at 1.0 MHz Gain at 10 MHz Large signal: Full output ....min. Rate limit	 50 kHz — — 1 kHz 20 V/ms	 50 kHz — — 1 kHz 20 V/ms	 1.5 MHz 2 — 10 kHz 0.6 V/μ-sec	 30 MHz ▼ 40 4 0.1 MHz 8 V/μ-sec	 4 MHz 6 — 8 kHz 0.5 V/μ-sec	 4 MHz 6 — 8 kHz 0.5 V/μ-sec	 100 MHz 140 14 300 kHz 200 V/μ-sec
3. **INPUT VOLTAGE RANGE** Voltage range, both inputs Voltage range, between inputs ....abs. max. CMRR, DC .... min.	 ±0.2 V 2.7 V 1000:1	 ±0.5 V 2.7 V 5000:1	 ±10 V 30 V 1000:1	 ±10 V 30 V 5,000:1	 ±10 V 5 V 20,000:1	 ±10 V 5 V 20,000:1	 ±10 V 5 V 1000:1
4. **INPUT IMPEDANCE** Between inputs Negative input to common Positive input to common	 10^{11}Ω ‖ 6 pF 10^{12}Ω ‖ 6 pF 10^{12}Ω ‖ 6 pF	 0.4 MΩ ‖ 6 pF 15 MΩ ‖ 6 pF 15 MΩ ‖ 6 pF	 10^{11}Ω ‖ 6 pF 10^{12}Ω ‖ 6 pF 10^{12}Ω ‖ 6 pF	 10^{11}Ω ‖ 3 pF 10^{12}Ω ‖ 6 pF 10^{12}Ω ‖ 6 pF	 5MΩ ‖ 5 pF $2(10^9)$Ω ‖ 27 pF $2(10^9)$Ω ‖ 27 pF	 5MΩ ‖ 5 pF $2(10^9)$Ω ‖ 27 pF $2(10^9)$Ω ‖ 27 pF	 220 kΩ ‖ 6 pF 33 MΩ ‖ 0.01μF 33 MΩ ‖ 6 pF
5. **INPUT VOLTAGE OFFSET** Zero adjustment (external) Vs Temp. (+10°C to +60°C), ...max. Vs Temp. (−25°C to +85°C), ...max. Vs Time (per day) Vs Time (½ hour)	 10 kΩ Rhst. 3 mV 6 mV 50 μV 10 μV	 10 kΩ Rhst. 3 mV 6 mV 50 μV 10 μV	 5 kΩ Rhst. 3 mV 6 mV 50 μV 10 μV	 10 kΩ & 250 kΩ Pot. 3 mV 6 mV 50 μV 10 μV	 2.5 kΩ Pot. 1 mV 3 mV 25 μV 10 μV	 2.5 kΩ Pot. 1 mV 3 mV 25 μV 10 μV	 50 kΩ Rhst. 2.5 mV 6 mV 100 μV 15 μV
6. **INPUT CURRENT OFFSET** 25°C ....max. Vs Temp. (+10°C to +60°C), ...max. Vs Temp. (−25°C to +85°C), ...max. Vs Time (per day) Vs Time (½ hour)	 −100 pA 1 nA 10 nA 3 pA 1 pA	 ±50 nA * 200 nA 440 nA 5 nA 0.5 nA	 −150 pA 1 nA 10 nA 3 pA 1 pA	 −150 pA 1 nA 10 nA 3 pA 1 pA	 +20 nA 20 nA 45 nA 1 nA 0.1 nA	 ±4 nA ** 4 nA 10 nA 1 nA 0.1 nA	 ±50 nA* 150 nA 300 nA 30 nA 3 nA
7. **INPUT NOISE** (a) Flicker (0.016 to 1.6 Hz) voltage p-p current p-p (b) Broadband (1.6 to 160 Hz) voltage rms current rms (c) Broadband (0.16 to 16 kHz) voltage rms current rms	 5 μV 2 pA 2 μV 3 pA 2 μV 3 pA	 5 μV 0.25 nA 1 μV 30 pA 1 μV 30 pA	 5 μV 2 pA 2 μV 1 pA 2 μV 3 pA	 5 μV 2 pA 2 μV 1 pA 2 μV 3 pA	 10 μV 0.05 nA 10 μV 6 pA 10 μV 6 pA	 10 μV 0.05 nA 10 μV 6 pA 10 μV 6 pA	 5 μV 0.5 nA 1 μV 600 pA 1 μV 600 pA
8. **OUTPUT (−25°C to +85°C)** Voltage Current Load (rated)	 ±1 V ±2 mA 500 Ω	 ±1 V ±2 mA 500 Ω	 ±11 V ±2.2 mA 5 kΩ	 ±11 V ±2.2 mA 5 kΩ	 ±11 V ±2.2 mA 5 kΩ	 ±11 V ±2.2 mA 5 kΩ	 ±10 V ±20 mA 500 Ω
9. **POWER REQUIREMENTS ‡** Voltage Current from positive supply: (Quiescent) (Full Load) Current from negative supply: (Quiescent) (Full Load)	 ±1.35 V 0.8 mA 2.8 mA 0.8 mA 2.8 mA	 ±1.35 V 0.4 mA 2.4 mA 0.4 mA 2.4 mA	 ±15 V 4.6 mA 4.6 mA 4.6 mA 6.8 mA	 ±15 V 6.6 mA 6.6 mA 6.6 mA 8.8 mA	 ±15 V 6 mA 6 mA 6 mA 8.2 mA	 ±15 V 6 mA 6 mA 6 mA 8.2 mA	 ±15 V 4 mA 23 mA 4 mA 23 mA
10. **TEMPERATURE RANGE** (degrees Centigrade) Operating: Rated Derated specifications ......max. Storage ....max.	 −25 to +85 −55 to +100 −62 to +125	 −25 to +85 −55 to +100 −62 to +125	 −25 to +85 −55 to +100 −62 to +125	 −55 to +125 −62 to +150	 −25 to +85 −55 to +100 −62 to +125	 −25 to +85 −55 to +100 −62 to +125	 −25 to +85 −55 to +100 −62 to +125
PRICE (quantity 1-4) Price of "Alternate Forms" may be slightly different. Prices may change without notice.	$145	$85	$135	$180	$98	$118	$118
ALTERNATE FORMS These units belong in the same family as the prototype because they have nearly equivalent circuit configurations. They may differ significantly from the listed types in electrical or physical characteristics, or application considerations. Philbrick Researches welcomes your inquiry regarding these and other modified forms of standard units.	**P12Q** ■ $145	**P18Q** ■ $85	**PP25C** and **P25C** ■ have input currents approximately 1/10 of those given for **PP25A** at any given temperature. $145 **P25A** ■ $135	**P25AH** ▼ ■ $154	**PP35A1** and **P35A1** ■ are units selected for less than 1 mV input voltage offset (−25°C to +85°C). $128 **P35A** ■ $98	**PP35C1** and **P35C1** ■ are units selected for less than 1 mV input voltage offset (−25°C to +85°C). $128 **P35C** ■ $118	**P45A** ■ $118
UTILITY GRADE Where indicated a utility grade equivalent denoted by the letter U following the model designation, is available at reduced price. Utility grade amplifiers have identical performance with their premium grade equivalents in the temperature range 0-60°C. Storage temperatures below −55°C and above +85°C and certified test data are not available.	**EP12QU** ▲ $108 **PP12QU** $108	**EP18QU** ▲ $59 **PP18QU** $59	**EP25AU** ▲ $85 **PP25AU** $79		**EP35AU** ▲ $60 **PP35AU** $54		**EP45AU** ▲ $87 **PP45U** $89

SUGGESTED BOOSTER TYPES (used with operational amplifiers for voltage or current boost; connected inside the loop)

		Physical Form	Price (quantity 1-4)
P66A	delivers ±10 V at ±100 mA with external "Boost" resistors connected; ±20 mA without.	P	$39
PP66A	delivers same power output as Model P66A.	PP	$40
P5	delivers ±10 V at ±20 mA; physical companion of P2A.	P2A	$48
OSPB -50/50	delivers ±50 V at ±50 mA with external "Boost" resistors connected; ±10 mA without; has DC gain of 7; requires ±60 V supplies.	OSP	$85
OSPB-100/10	delivers ±100 VDC at ±10 mA with external "Boost" resistors connected; ±1.5 mA without; has DC gain of 20; requires ±120 VDC supplies.	OSP	$85

FLAT-PROFILE PACKAGE

"FLAT-PROFILE" amplifiers (FP), only 0.4" in height, are available in OEM quantities to permit 0.5" printed circuit board spacing. Most "PP" amplifiers described above and some boosted models not available in the "PP" package may be ordered in the "FP" model.

PP45C Ultra wideband Large output current Input current compensated	PP45L Large output current	PP55A Low cost Premium grade construction	PP65A Versatile	PP65C Versatile Input current compensated	PP65AH Wideband Versatile	PP75A High input impedance	PP85A Differential Low voltage offset	PP85C Differential Low voltage offset Input current compensated
50,000 200,000 300,000 20,000 100,000	50,000 200,000 300,000 20,000 100,000	20,000 40,000 60,000 10,000 30,000	40,000 75,000 180,000 20,000 50,000	40,000 75,000 180,000 20,000 50,000	40,000 75,000 180,000 20,000 50,000	20,000 40,000 80,000 10,000 40,000	50,000 90,000 200,000 20,000 60,000	50,000 90,000 200,000 20,000 60,000
100 MHz 140 14 300 kHz 200 V/μ-sec	1.5 MHz 2 — 10 kHz 0.6 V/μ-sec	1.5 MHz 3 — 20 kHz 1.5 V/μ-sec	1.5 MHz 3 — 20 kHz 1.5 V/μ-sec	1.5 MHz 3 20 .kHz 1.5 V/μ-sec	20 MHz 25 3 75 kHz 5 V/μ-sec	1.5 MHz 3 — 20 kHz 1.5 V/μ-sec	2 MHz 3 — 10 kHz 0.6 V/μ-sec	2 MHz 3 — 10 kHz 0.6 V/μ-sec
±5 V 5 V 300:1	±10 V 5 V 1000:1	±10 V 5 V 1000:1	±10 V 5 V 1000:1	± 5 V 5 V 300:1	±10 V 5 V 1000:1	±10 V 10 V 1000:1	±11 V 5 V 20,000:1	±11 V 5 V 20,000:1
220 kΩ ∥ 6 pF 15 MΩ ∥ 0.01μF 15 MΩ ∥ 6 pF	220 kΩ ∥ 6 pF 33 MΩ ∥ 1000 pF 33 MΩ ∥ 6 pF	200kΩ ∥ 7pF 15MΩ ∥ 400pF 15MΩ ∥ 8pF	300kΩ ∥ 6pF 44MΩ ∥ 400pF 44MΩ ∥ 6pF	300kΩ ∥ 6pF 22MΩ ∥ 400pF 22MΩ ∥ 6pF	300kΩ ∥ 6pF 44MΩ ∥ 400pF 44MΩ ∥ 6pF	10MΩ ∥ 6pF 500MΩ ∥ 400pF 500MΩ ∥ 6pF	330kΩ ∥ 6pF 500MΩ ∥ 6pF 500MΩ ∥ 6pF	330kΩ ∥ 6pF 500MΩ ∥ 6pF 500MΩ ∥ 6pF
50 kΩ Rhst. 2.5 mV 6 mV 100 μV 15 μV	50 kΩ Rhst. 2.5 mV 6 mV 100 μV 15 μV	50 kΩ Rhst. 2 mV 6 mV 100 μV 25 μV	50 kΩ Rhst. 1.5 mV 4 mV 50 μV 10 μV	50 kΩ Rhst. 1.5 mV 4 mV 50 μV 10 μV	50 kΩ Rhst. 1.5 mV 4 mV 50 μV 10 μV	50 kΩ Rhst. 3 mV 12 mV 100 μV 25 μV	50 kΩ Rhst. 1 mV 3 mV 50 μV 10 μV	50 kΩ Rhst. 1 mV 3 mV 50 μV 10 μV
±50 nA 50 nA 150 nA 30 nA 3 nA	±50 nA* 150 nA 300 nA 30 nA 3 nA	±50 nA* 300 nA 600 nA 30 nA 3 nA	±50 nA* 150 nA 300 nA 10 nA 1 nA	±50 nA 50 nA 100 nA 10 nA 1 nA	±50 nA* 150 nA 300 nA 10 nA 1 nA	+ 20 nA 20 nA 60 nA 1 nA 0.1 nA	±50 nA* 150 nA 300 nA 5 nA 0.5 nA	±50 nA ** 50 nA 100 nA 5 nA 0.5 nA
5 μV 0.5 nA 1 μV 600 pA 1 μV 600 pA	5 μV 0.5 nA 1 μV 60 pA 1 μV 60 pA	15 μV 1 nA 2 μV 100 pA 2 μV 100 pA	10 μV 0.5 nA 1 μV 60 pA 1 μV 60 pA	10 μV 0.5 nA 1 μV 60 pA 1 μV 60 pA	10 μV 0.5 nA 1 μV 60 pA 1 μV 60 pA	20 μV 0.05 nA 10 μV 6 pA 10 μV 6 pA	5 μV 0.25 nA 1 μV 30 pA 1 μV 30 pA	5 μV 0.25 nA 1 μV 30 pA 1 μV 30 pA
±10 V ±20 mA 500 Ω	±10 V ±20 mA 500 Ω	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ
±15 V 4 mA 23 mA 4 mA 23 mA	±15 V 4 mA 23 mA 4 mA 23 mA	±15 V 5.5 mA 7.7 mA 5.5 mA 5.5 mA	±15 V 5.5 mA 7.7 mA 5.5 mA 5.5 mA	±15 V 5.5 mA 7.7 mA 5.5 mA 5.5 mA	±15 V 5.5 mA 7.7 mA 5.5 mA 5.5 mA	±15 V 5.5 mA 7.7 mA 5.5 mA 5.5 mA	±15 V 4 mA 4 mA 4 mA 6.2 mA	±15 V 4 mA 4 mA 4 mA 6.2 mA
−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125
$135	$95	$49	$60	$75	$64	$98	$60	$80
P45C ■ $133	**P45AL** ■ $95 **PP45CL** and **P45CL** ■ have input current offsets and common mode parameters identical to those of **PP45C** $110	**PP55AH** and **P55AH** ● are stable wide-band versions. $53 **P55A** ● $49	**P65A** ■ $65 **PP65Q** $64 and **P65Q** ■ $69 have ±0.9 mA quiescent battery drain, ±0.5 mA full output.	**PP65CH** $79 and **P65CH** ■ $84 are wide-band versions **P65C** ■ $80	**P65AH** ■ $69	**P75A** ■ $98	**PP85A1** and **P85A1** ■ are units selected for less than 1 mV input voltage offset (−25°C to +85°C). $70 and $75 **P85A** ■ $65	**P85C** ■ $80
	EP45ALU ▲ $63 **PP45LU** $65	**EP55AU** ◆ $19 **PP55AU** $15 **EP55AHU** ◆ $23 **PP55AHU** $19	**EP65AU** ▲ $31 **PP65AU** $30 **EP65QU** ▲ $35 **PP65QU** $34		**EP65AHU** ▲ $35 **PP65AHU** $34	**P75AU** ■ $68 **PP75AU** $68	**EP85AU** ▲ $31 **PP85AU** $25	

PHILBRICK
RESEARCHES

Allied Drive at Route 128, Dedham, Massachusetts 02026

U.S.A.

CHARACTERISTICS Typical at $+25°C$ unless otherwise indicated	Q85AH Differential wideband Low voltage offset	SP2A Differential Ultra low offset current Floating input	SP65A † Stabilized	SP65AH † Stabilized Wideband	SP656 † Stabilized Large output current	SP456 † Stabilized Wideband Large output current
1. VOLTAGE GAIN (DC open loop) At $+25°C$, rated load, ...min. 10 kΩ load, ...min. 100 kΩ load, ...min. At $-25°C$, rated load, ...min. At $+85°C$, rated load, ...min.	20,000 40,000 80,000 15,000 15,000	20,000 40,000 150,000 10,000 (0°C) 10,000 (65°C)	10^7 2×10^7 4×10^7 5×10^6 4×10^7	10^7 2×10^7 4×10^7 5×10^6 4×10^7	5×10^7 10^8 2×10^8 2.5×10^7 10^8	10^8 4×10^8 4×10^8 5×10^7 2×10^8
2. RESPONSE (open loop, inverting) Small signal: Unity gain-bandwith ....min. Gain at 1.0 MHz Gain at 10 MHz Large signal: Full output ....min. Rate limit	30 MHz ▼ 50 5 0.1 MHz 8 V/µ-sec	75 kHz — — 1.1 kHz .066 V/µ-sec	1.5 MHz 3 — 20 kHz 1.5 V/µ-sec	20 MHz 25 2.5 75 kHz 5 V/µ-sec	1.5 MHz 3 — 20 kHz 1.5 V/µ-sec	100 MHz 140 14 300 kHz 200 V/µ-sec
3. INPUT VOLTAGE RANGE Voltage range, both inputs Voltage range, between inputs ....abs. max. CMRR, DC .... min.	±11 V 10 V 20,000:1	±300 V 15 V Infinite	±0.1 V 0.5 V —	±0.1 V 0.5 V —	±0.1 V 0.5 V —	±0.1 V 0.5 V —
4. INPUT IMPEDANCE Between inputs Negative input to common Positive input to common	2MΩ ‖ 3pF 500MΩ ‖ 5pF 500MΩ ‖ 5pF	10^{10}Ω ‖ 500 pF 10^{12}Ω ‖ 5 pF 10^{12}Ω ‖ 5 pF	— 1.3MΩ ‖ 300pF —	— 1.3 MΩ ‖ 300pF —	— 1.3 MΩ ‖ 300pF —	— 1.3 MΩ ‖ 0.01µF —
5. INPUT VOLTAGE OFFSET Zero adjustment (external) Vs Temp. ($+10°C$ to $+60°C$), ...max. Vs Temp. ($-25°C$ to $+85°C$), ...max. Vs Time (per day) Vs Time (½ hour)	10 kΩ & 250 kΩ Pot. 1 mV 3 mV 50 µV 10 µV	Built-in — 6 mV (0° to 65°C) 100 µV 10 µV	1MΩ & 100 kΩ Pot. 20 µV (5 µV typ.) 50 µV (20 µV typ.) 1 µV 1 µV	1MΩ & 100 kΩ Pot. 20 µV (5 µV typ.) 50 µV (20 µV typ.) 1 µV 1 µV	1MΩ & 100 kΩ Pot. 20 µV (5 µV typ.) 50 µV (20 µV typ.) 1 µV 1 µV	1MΩ & 100 kΩ Pot. 20 µV (5 µV typ.) 50 µV (20 µV typ.) 1 µV 1 µV
6. INPUT CURRENT OFFSET 25°C ....max. Vs Temp. ($+10°C$ to $+60°C$), ...max. Vs Temp. ($-25°C$ to $+85°C$), ...max. Vs Time (per day) Vs Time (½ hour)	220 nA 220 nA 440 nA 5 nA 0.5 nA	±1 pA — 10 pA (0° to 65°C) 0.1 pA 0.01 pA	10 pA 30 pA 100 pA 10 pA 2 pA	10 pA 30 pA 100 pA 10 pA 2 pA	10 pA 30 pA 100 pA 10 pA 2 pA	10 pA 30 pA 100 pA 10 pA 2 pA
7. INPUT NOISE (a) Flicker (0.016 to 1.6 Hz) voltage p-p current p-p (b) Broadband (1.6 to 160 Hz) voltage rms current rms (c) Broadband (0.16 to 16 kHz) voltage rms current rms	5 µV 0.25 nA 1 µV 30 pA 1 µV 30 pA	1 µV 1 fA 10 µV p-p — 10 µV 500 pA	6 µV 0.1 nA 10 µV p-p — 1 µV 60 pA	6 µV 0.1 nA 10 µV p-p — 1 µV 60 pA	6 µV 0.1 nA 10 µV p-p — 1 µV 60 pA	6 µV 0.1 nA 10 µV p-p — 1 µV 600 pA
8. OUTPUT ($-25°C$ to $+85°C$) Voltage Current Load (rated)	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±10 V ±20 mA 500 Ω	±10 V ±20 mA 500 Ω
9. POWER REQUIREMENTS ‡ Voltage Current from positive supply: (Quiescent) (Full Load) Current from negative supply: (Quiescent) (Full Load)	±15 V 6 mA 6 mA 6 mA 8.2 mA	±15 V 8 mA 8 mA 6 mA 8.2 mA	±15 V 8 mA 10 mA 7 mA 7 mA	±15 V 8 mA 10 mA 7 mA 7 mA	±15 V 8.75 mA 28 mA 8.75 mA 28.5 mA	±15 V 5 mA 24.5 mA 4.5 mA 24 mA
10. TEMPERATURE RANGE (degrees Centigrade) Operating: Rated Derated specifications ......max. Storage ....max.	-55 to +125 -62 to +150	0 to +65 −25 to +85 −55 to +85	−25 to +85 −45 to +85 −55 to +85	−25 to +85 −45 to +85 −55 to +85	−25 to +85 −45 to +85 −55 to +85	−25 to +85 −45 to +85 −55 to +85
PRICE (quantity 1-4) Price of "Alternate Forms" may be slightly different. Prices may change without notice.	$161	$180	$180	$189	$195	$227
ALTERNATE FORMS These units belong in the same family as the prototype because they have nearly equivalent circuit configurations. They may differ significantly from the listed types in electrical or physical characteristics, or applications considerations. Philbrick Researches welcomes your inquiry regarding these and other modified forms of standard units.	**P85AH** ▼■ $98	**P2A** $227 is a wire-in version of **SP2A**. It has no provision for a driven guard **SP2B** $195 has 20 mA output current capability. **SP102** $295 has ±100 V @ 10 mA output capability.				
UTILITY GRADE Where indicated a utility grade equivalent denoted by the letter U following the model designation, is available at reduced price. Utility grade amplifiers have identical performance with their premium grade equivalents in the temperature range 0-60°C. Storage temperatures below −55°C and above +85°C and certified test data are not available.		**P2AU** ▲▲ $130 **SP2AU** ▲▲ $138 **SP2BU** ▲▲ $145				

LEGEND

- M — mega — 10^6
- k — kilo — 10^3
- m — milli — 10^{-3}
- µ — micro — 10^{-6}
- n — nano — 10^{-9}
- p — pico — 10^{-12}
- f — femto — 10^{-15}

FOOTNOTES

■ A plug-in version in bright-metal case having similar performance. Voltage offset adjustment built-in.

◆ A plug-in epoxy version having similar performance. Voltage offset adjustment external.

● A plug-in version in bright-metal case having similar performance. No built-in voltage offset adjustment.

▲ A plug-in epoxy version having similar performance Voltage offset adjustment built-in.

* With specified external current trim resistors installed. P models have built-in current trim resistors.

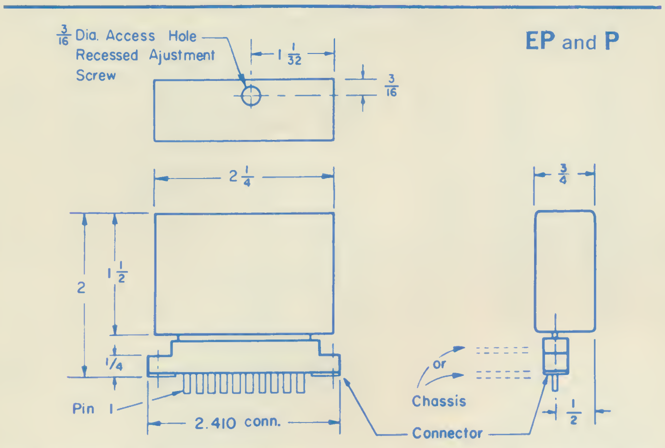
** With "Trim I" terminal grounded. Can be trimmed to zero by voltage bias (±5 V Max.) applied to "Trim I" terminal.

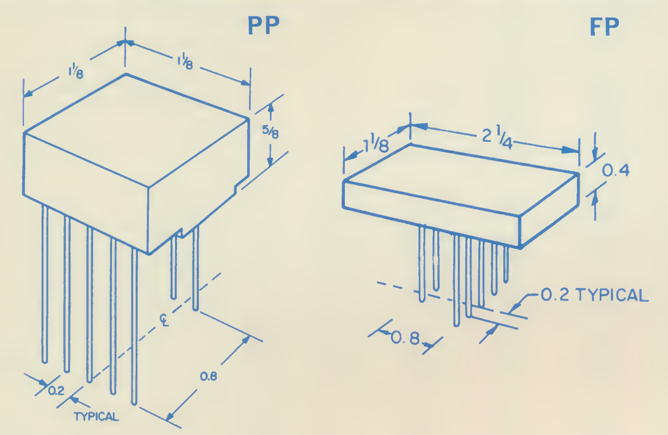
▼ Roll-off network connected externally.

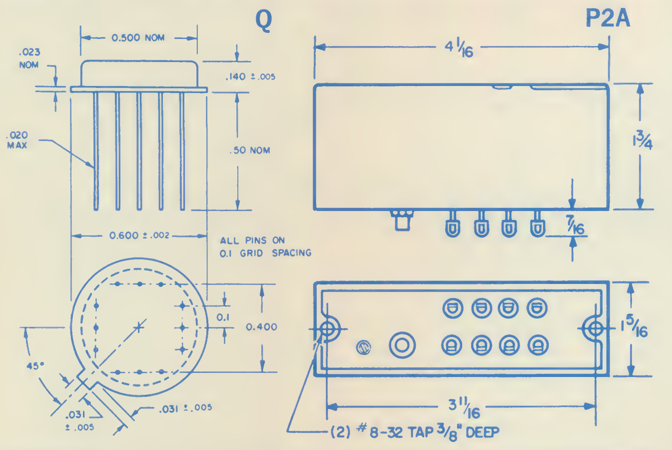
† Specifications shown are for units with mechanical chopper; 6.3 VAC, 50-80 cps at 80 mA is required. Units with photochopper are available for operation below +65°C. In addition to 6.3 VAC, 50-80 cps, 1 mA, the photochopper also requires 115 VAC, 5 mA, at the same frequency and phase.

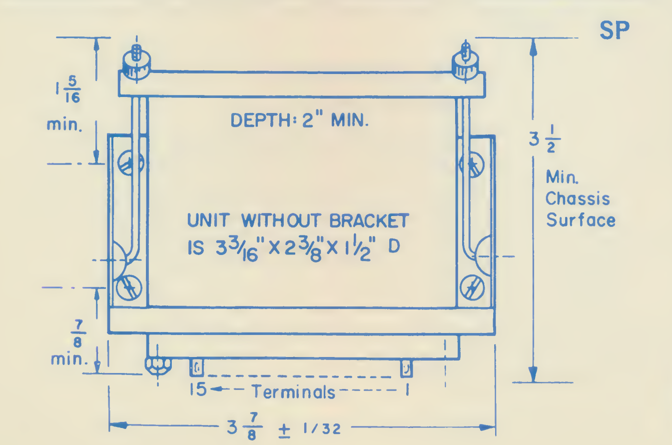
‡ At +85°C power requirements will be 10% higher than those stated at +25°C. For maximum power requirements at any temperature add ±10%.

▲▲ These utility versions have wider tolerances for voltage offset vs temperature, and input current, than premium equivalents.









UTILITY-GRADE

Philbrick Utility-Grade Amplifiers, identified by the letter "U" following the family number (e.g.PP85AU), are identical to premium-grade prototypes in circuitry, layout, manufacturing techniques, and the exclusive use of silicon transistors and first-grade passive components from leading U. S. manufacturers.

The substantial price difference between premium and utility-grade amplifiers is achieved by the following means:

The use of silicon transistors encapsulated in highly moisture-resistant silicone plastic (Note: not epoxy!) instead of hermetically-sealed amplifiers.

Use of capacitors which are guaranteed from −55 to +85°C, instead of the −65 to +125°C units normally used in Premium-Grade products.

All room-temperature tests are carried out with the thoroughness that has earned Philbrick an enviable reputation for reliability; **complete** temperature tests are run on representative samples of each production run to confirm compliance with published specifications.

Use of date codes and go-no-go tests instead of serial numbers and recording of data as normally required for all premium units (Government Inspection and/or certified test results are available, upon request, for **premium** units.)

In performance, the Utility-Grade amplifiers (except those in the P2 Series) are identical to their Premium-Grade counterparts. As temperature tests are conducted on samples only, tolerances outside the 10°–60°C range are relaxed as compared with the corresponding specifications for the premium amplifier.

Philbrick Utility-Grade amplifiers may be substituted in virtually all applications for which their Premium-Grade counterparts are and have been originally recommended.

CURRENT COMPENSATION

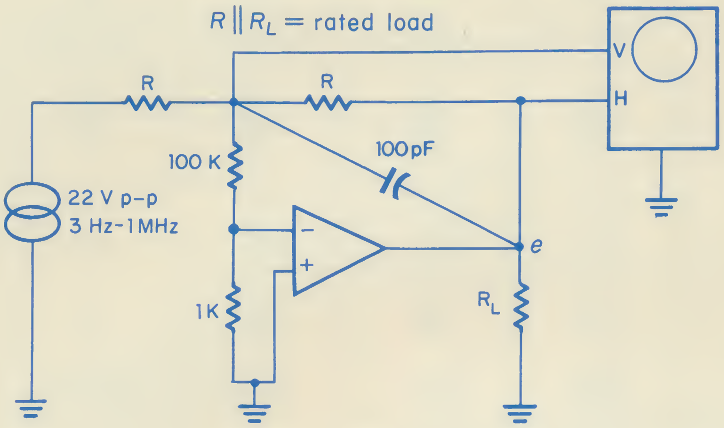
Philbrick differential operational amplifier families P35 through P85 contain input stages with matched pairs of junction transistors in a common emitter configuration. Emitter current being kept constant, each transistor requires a "housekeeping" current into its base amounting to emitter current divided by β (current gain). By selecting high-β transistors and low emitter currents, these base currents can be made as small as 10^{-8} amperes, but they can never be eliminated, and they increase as temperature decreases. If the base currents of input transistors are not supplied by current sources within the amplifier, an output voltage error will result because this offset current produces a voltage drop across the feed-back impedance (in an inverter) or the signal source impedance (in a voltage follower).

The simplest form of base current supply is a resistor from +B to each base. P45A, P55A, P65A and P85A families have these built in, while the proper resistance values for external installation are marked on their PP equivalents. Although these current trim resistors are inexpensive, they are most effective within narrow temperature limits and where high common-mode voltages do not occur. After all, β, and with it base current do change with temperature, and a resistor is a constant current source only as long as the voltage across it remains constant!

Philbrick Current Compensated Amplifiers, identified by the letter C following the family number, have built-in base current sources which closely track current demand over the entire operating temperature range.

The P35C and P85C series contain a sophisticated compensating circuit which leaves the outstanding common mode voltage rejection ratio, the common mode voltage range, and the input impedances unaffected. An additional feature of this compensating circuit is a provision for nulling either input current completely by applying an adjustable voltage bias (±5 volts maximum) to a terminal provided for the purpose. The P45C and P65C series contain a simpler compensating circuit which provides a fivefold decrease in offset current over the entire temperature range, but also reduces the common mode rejection ratio, the common mode voltage range, and the input impedance.

AMPLIFIER TEST CIRCUITS

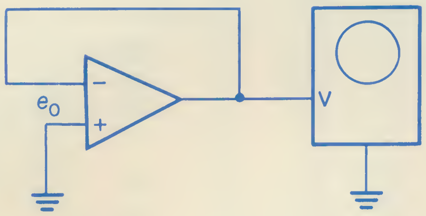


OPEN LOOP GAIN & OUTPUT CAPABILITY

DC open loop gain, A, and output capability may be measured at 20 Hz. Of chopper stabilized amplifiers, only the main amplifier gain is measured in this manner, overall DC gain being too high to measure. For SP2A the gain measurement should be carried out at no more than 3 Hz.

$$A = 101 \frac{e_H}{e_V}$$

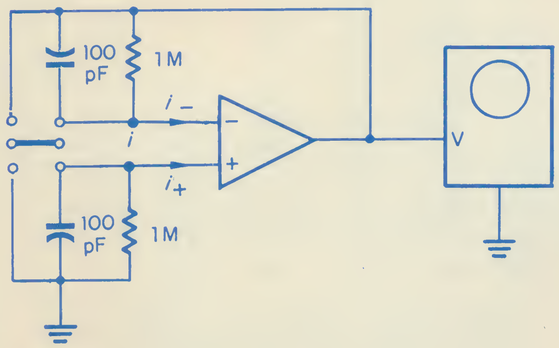
$$e_O = e_V$$



VOLTAGE OFFSET

Voltage offset, e_O, vs. temperature and/or time may be measured after the voltage offset central has been adjusted for zero output at room temperature. For best accuracy allow the amplifier to warm up for 30 minutes before adjusting to zero.

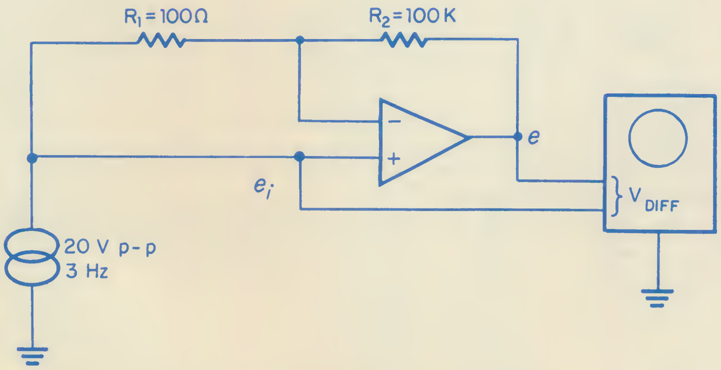
MEASURE	SWITCH
i_+	UP
TRACK	CENTER
i_-	DOWN



INPUT CURRENT

Input currents should be measured after the voltage offset has been nulled. If amplifiers have too little input current to be measured in this manner (SP2A, P25A, Q25AH, chopper stabilized amplifier) the 1MΩ resistors should be omitted, and the output change timed. $i = C\,de/dt$ or 1 pA = 10 mV/sec.

i_-	TRACK	i_+
$i_- = \frac{+e_V}{1\,\text{M}\Omega}$	$i_+ - i_- = \frac{-e_V}{1\,\text{M}\Omega}$	$i_- = \frac{-e_V}{1\,\text{M}\Omega}$



COMMON MODE REJECTION

The common mode rejection ratio measurement must be carried out using oscilloscope having itself good CMRR. It will be found that the CMRR of the SP2A is too high to measure in this manner.

$$\text{CMRR} = \left(\frac{e_i}{e - e_i}\right)\left(\frac{R_2}{R_1} + 1\right) \text{ provided } A \gg \text{CMRR}$$

Engineering Representatives

Alabama	Huntsville	205-536-8393
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California	Los Angeles	213-937-0780
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